Study on conservation of archaeological waterlogged wood in Vietnam(Abstract_要旨)

AUTHOR(S):

Nguyen, Duc Thanh

（ 続紙 1 ）

京都大学	博士（　　農　学　　）	氏名	Nguyen　　Duc　　Thanh
論文題目	Study on conservation of archaeological waterlogged wood in Vietnam （ベトナムの遺跡出土木材の保存に関する研究）		

（論文内容の要旨）

Archaeological waterlogged wood (WW) is one significant part of the archaeological resource because it provides evidence for the primary raw material used for structures, artifacts, and fuels throughout most of human existence. Therefore, conservation of cultural heritage is fundamental for conveying culture, traditions, ways of thinking and behaving to future generations. The preservation has an impressive impact on society from a political, sociological and anthropological point of view.

Vietnam has a variety type of WWs unearthed from archaeological sites such as the ancient shipwrecks under the seabed in the south of Vietnam, wooden artifacts under the ground in the Thang Long heritage site - Hanoi, Bach Dang stake yard - Quang Ninh, and so on. Among them, the Thang Long Imperial Citadel site is one of the most important heritage sites, and it was named on the World Heritage list by UNESCO's World Heritage Committee in 2010.

During the archaeological investigation, a significant proportion of wooden artifacts was unearthed from the Thang Long archaeological site. Some of them remain buried *in-situ* while others were salvaged from the site. These cultural properties are continually threatened by environmental impacts since the long-term protections are not implemented. Given the current condition of heritage, it is recommended that the immediate conservation treatment should be taken into account for preserving these artifacts. The conservation of cultural relics at Thang Long Imperial Citadel site, therefore, is one of the important plans put forth by the Government of Vietnam.

Conservation treatment for WWs has been developed in many countries, including Japan. However, conservation of WWs is a quite difficult topic, especially in many newly detected historical, cultural heritage sites in developing country like Vietnam where both technology and human resource are very limited. It is necessary to be taken into consideration for further study and conservation to achieve the expectation of not only conservation of such kind of cultural relics but also on the establishment of conservation method for WWs.

This study aimed to establish appropriate preservation technology for the WWs obtained from the Thang Long Imperial Citadel site, Hanoi and this is the first study on conservation of WWs in Vietnam.

Chapter 1 introduced the background, objective and outline of the study. Additionally, the chapter also introduced conservation treatment methods currently applied to WWs.

Chapter 2 summarizes the species identification and physicochemical properties of 15 waterlogged hardwood samples obtained from Thang Long archaeological site. The anatomical features showed that those samples were belonging to 10 different genera. The measurements

on physical and chemical characteristics of WWs showed different levels of wood degradation. Chemical analysis also confirmed the degree of wood degradation. Interestingly, the deterioration of *Erythrophleum fordii* Oliv. wood was very limited even after several hundred years of burial.

In Chapter 3, the natural durability of the *E. fordii* wood against white rot fungi was evaluated to elucidate the excellent state of preservation of this timber in the soil, and for determining appropriate procedures to conserve this timber. The characteristic of a fungi-resistance *E. fordii* wood is of particular relevance to the highly-condensed lignin content as well as the compactness of wood fibers.

General preservation treatment methods using PEG4000, trehalose, and feather keratin were examined with seven WW species (Chapter 4). The results showed that the dimensional stability of WWs was significantly improved after the treatments. Based on the improved dimensional stability of wood, shortened impregnation time, removability of chemical, and aesthetic results obtained from the treatment, feather keratin showed a good performance on average as a preservation agent and can be applied practically for Vietnamese WWs.

In order to establish the suitable treatment conditions for Vietnamese WWs, steady-state diffusion coefficients of PEG4000, trehalose, and feather keratin through eight WW species were discussed (Chapter 5). The diffusion coefficients were strongly affected by wood species, the anisotropic structures of wood, and conservation agents. Based on diffusion coefficient, expected impregnation time for dip-diffusion treatments can be estimated.

In Chapter 6, a new method utilizing the *in-situ* crosslinking reaction of the hydrophilic polymer to enhance recoverability of WWs from unexpected drying was developed. The results showed that treatment with crosslinked sodium polyacrylate (PAANa) resulted in excellent shape recovery of WWs after multiple drying-rewetting cycles, while the recovery was not complete in the untreated samples. The cross-linking PAANa treatment could be used to provide resistance and recovery after unexpected drying and may be used either as the primary conservation method or as a pretreatment in conjunction with other established conservation methods. Finally, in Chapter 7, the general conclusion was provided to summarize all the results and findings of this study.

In conclusion, the species identification and physicochemical properties of 15 WW samples were examined. It is revealed that the *E. fordii* commonly excavated from the site is extremely resistant to biological degradation. This is due to condensed lignin content as well as the structural rigidity of this species. General preservation treatment methods using PEG, trehalose, and feather keratin were applied for the conservation of small WW samples. Among them, feather keratin exhibited high performance on average as a potential preservation material. It was clarified that the diffusion coefficient of preservatives depends on wood species, and pointed out the necessity of deciding treatment conditions for each tree species. Finally, a new method of protecting excavated wood from unexpected drying by utilizing the *in-situ* crosslinking reaction of the hydrophilic polymer was developed. The results of this study can be applied practically for the conservation of WWs in Vietnam.

（続紙 ２ ）

（論文審査の結果の要旨）

これまで、出土木材の保存処理に関する研究は温帯産の樹種からなる出土木材に対して高い寸法安定性を発現する薬剤の含浸に依存する傾向があり、必ずしもその原理的な部分が研究されてきていない。ベトナム産樹種の出土木材をはじめ、アジアの熱帯産の出土木材の化学的特徴、物理的性質などは未知な部分が多く、温帯産の樹種からなる出土木材とは、その性質を異にすることが多い。本研究は、ベトナム産の樹種について、その樹種がもつ固有の性質を把握し、その上で有効な薬剤含浸処理とその条件を明らかにするとともに、乾燥固化を防ぐ新しい処理について取りまとめたものであり、特に評価すべき点として以下の３点を挙げることができる。

１） タンロン皇城遺跡から発掘されたベトナム産材15点の出土木材の樹種を特定し、その組織構造の特徴や、化学組成および物理的性質を調査したところ、現地でLim材と呼ばれる高密度材が特に劣化の程度が低かった。そこで、現生材を用いて、その抽出成分の抗菌性や、木材の腐朽試験を実施したところ、抽出物には抗菌性成分は認められなかった。一方、腐朽試験の結果、縮合型リグニンを多く含む厚壁の木繊維の存在が腐朽を遅らせる要因と推察した。

２） PEG、トレハロース、ケラチンなどの汎用的な保存処理方法を比較検討した。ケラチン浸潤法は、色、薬剤の再溶脱性が良いなど、保存処理材として他にない特性が示された。また各処理方法における拡散係数は、出土木材の最大含水率に依存せず、樹種に依存することが明らかとなった。さらに拡散係数から最適処理時間を見積もることができ、現場の経験則に依存しない、現地産材に適した保存処理技術を向上させる可能性を示した。

３） 水浸出土木材にアクリル酸ナトリウムを減圧注入し、その組織内で架橋して超親水性ポリマーとする方法を考案した。この処理により、乾燥、湿潤の繰り返し処理後もほぼ100%形状復元する能力を付与することができた。したがって突発的な乾燥から文化財木製品表面を保護する方法として期待できる。

以上のように、本論文は保存薬剤の浸透性や寸法安定性の低い樹種が多い熱帯アジアの出土木材の保存処理を、各樹種の物理的性質や化学的性質を把握しながら開発する必要性があること示す先駆的な研究であり、木材解剖学、木材保存学、文化財科学の発展に寄与するところが大きい。

よって、本論文は博士（農学）の学位論文として価値あるものと認める。

なお、平成３０年３月１２日、論文並びにそれに関連した分野にわたり試問した結果、博士（農学）の学位を授与される学力が十分あるものと認めた。

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要旨公開可能日：　　年　　月　　日以降（学位授与日から３ヶ月以内）